MOJES

MALAYSIAN ONLINE JOURNAL OF EDUCATIONAL SCIENCES OKTOBER 2022, 10 (4)

EXAMINING SCIENCE TEACHERS' DESIGNING EXPERIMENT PERFORMANCES: AN EXAMPLE OF "CHANGING" VARIABLE

Gul UNAL COBAN
Science Education Department
Buca Faculty of Education, Dokuz Eylul University

***Merve KOCAGUL**
Science Education Department
Faculty of Education, Pamukkale University
mervekocagl@gmail.com

ABSTRACT

This study was aimed to determine science teachers' status about designing experiments which is one of the main components of inquiry-based learning and how given variable type affects this performance. Participants of the study, which was conducted in cross-sectional survey design, were 72 science teachers who were determined through convenience sampling. "Designing Experiments Performance Assessment Form (DEPAF)" developed by the researchers was used as data collection tool and obtained data were analyzed through "Designing Experiments Performance Assessment Rubric (DEPAR)" that were also developed by the researchers. Results indicated that science teachers were good at determining the purpose of the experiment, planning, collecting and interpreting data although they had problems in identifying variables and determining the validity and reliability of experimental data. Furthermore, it was found that science teachers who designed experiments with problems consisting of only independent variable had significantly higher scores in both total score of designing experiment performance and especially scores in planning, collecting and interpreting data than other teachers who designed experiments with problems having only dependent variable. It is hoped that obtained results, which can be thought as preliminary study to eliminate teachers' problems about experimentation, will contribute to literature.

Keywords: *Inquiry-Based Learning, Designing Experiments, Variable Type, Science Teachers*

INTRODUCTION

21st Century Skills and Inquiry-Based Learning

Needs in the changing world with the inclusion of technology into our lives are shaped based on the developments and current changings. This situation is also valid for societies, which are the base for states in terms of individual profile that they need. In recent years, many researchers suggest that students should have 21st century skills (Belet Boyacı & Güner Özer, 2019; Cohen et al., 2017; Farisi, 2016; Fandino Parra, 2013; Rahayu, 2017). These skills are defined as individuals' knowledge, competence, and specialty in basic fields (physics, mathematics, geology and etc.), learning and innovation, information, media and technology as well as life and career to take their places in work fields needed nowadays and in the future (Partnership for 21st Century Skills, 2009).

Gaining 21st century skills require instructional methods to teach these skills into question. These skills provide individuals to utilise their knowledge in the face of daily problems and require strong communication and collaboration skills, specialty in technology, innovative and creative thinking skills and problem-solving skills (Larson & Northern Miller, 2011). Similarly, in inquiry-based learning (IBL), individuals develop their knowledge literacy through information seeking, evaluating and transferring into different situations for solving the problem at hand, metacognitive skills through the awareness towards learning processes and social skills such as communication and collaboration through group work (Kuhlthau et al., 2015). Based on this similarity, IBL is seen as important for gaining 21st century skills (Chu et al., 2012; Kuhlthau et al., 2015).

Designing Experiments in IBL

Inquiry-based learning is defined as a hands-on learning approach which students make plans to answer the questions about natural world by working collaboratively, collect evidences, make explanations based on evidences and coordinating theory with evidences (Anderson, 2002). National Research Council (NRC) (1996) also describes inquiry-based learning as questioning for exploring scientific phenomena, conducting research, reaching conclusion, and evaluating the results. These two definitions emphasize some core features of IBL. Pedaste et al. (2015) made clear these common core features in different definitions by synthesizing various inquiry-based learning stages (Figure 1).

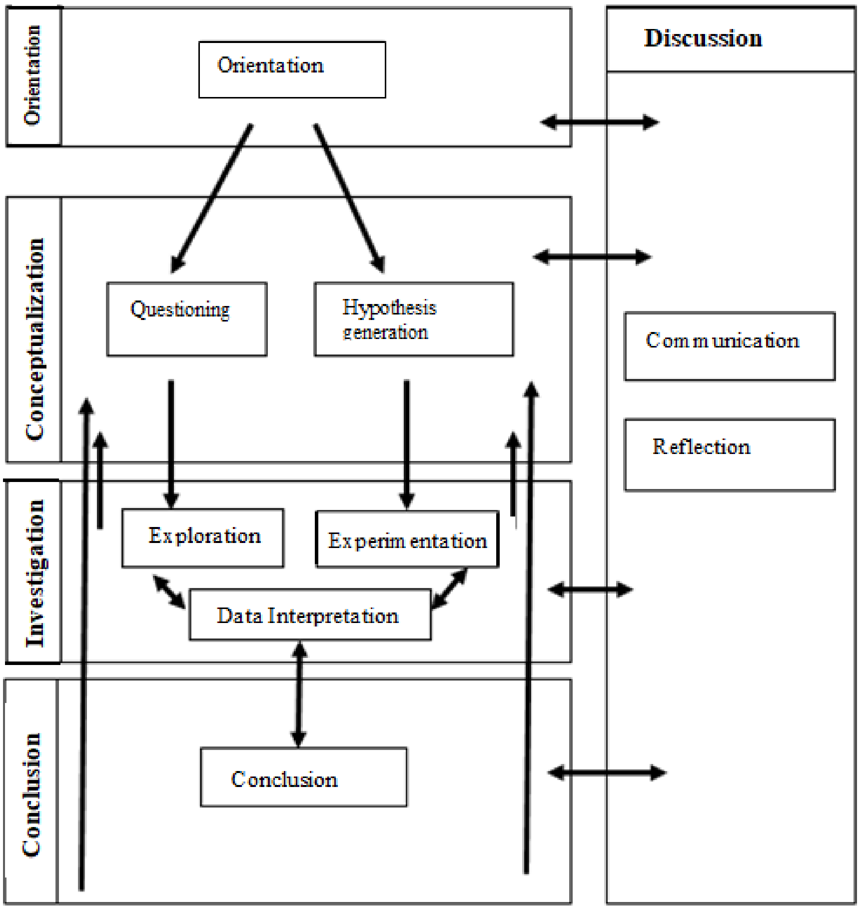


Figure 1. Inquiry-based learning stages (Pedaste et al., 2015).

Inquiry-based learning stages presented in Figure 1 also show teachers' skills and competencies needed for implementing an effective IBL into classroom clearly.

Experimenting provides learning motivation, develops mental and motor skills, provides to gain content knowledge and facilitates to build relationship between daily lives and science course (Ergin et al., 2005). In furtherance, Pyatt and Sims (2012) reported that experimenting regardless of real or virtual environment has an effect on conceptual change and attitudes towards using the laboratory. Another study indicated that science teachers saw experimenting as important in terms of developing students' observation skills, facilitating learning, providing students' collaboration and developing students' motor and reasoning skills (Yıldız et al., 2006). Based on these results, it was focused on experimentation stage of IBL in this study.

Factors Needed for Designing Experiment

Designing experiments correspondence to testing hypothesis and conducting it has some sub-components. According to Trnova and Trna (2006), experimentation process requires making plan and design for experiment, determining related equipment, explaining steps for conducting the experiment, collecting data and presenting them appropriately and analyzing the experiment's results (validity and reliability of data). Similarly, Ergin et al. (2005) expressed that experimentation process includes determining the purpose, gaining knowledge for the concept to be taught, identifying variables, providing equipment, explaining steps clearly, collecting and interpreting data and analyzing the validity and reliability of data. In another study, it was reported that having prior content knowledge was an essential factor to design and conduct experiment (van Riesen et al., 2018). Besides content knowledge, teachers' self-efficacy perceptions are also important because they shape the instruction (Lee & Houseal, 2003; Uluçınar Sağır & Aslan, 2009). The study by Zhou et al. (2016) revealed another important factor that presenting only test conditions without data affected students' control of variables (CoV) strategy skills positively, students used CoV strategy better in physics rather than daily life situations and students perceived non-influential variable and untestable variable as equivalent.

Prior Studies About Designing Experiments

In order to implement IBL effectively, teachers must have solid understanding and skills towards the components of IBL especially in designing experiments in the context of this study. However, there are studies on teachers' difficulties and deficiencies about designing or conducting experiments. In one of these studies regarding determining the purpose, researchers found that science teachers saw some experiments' purposes such as the effects of experiments on making new research, identifying some daily lives materials, learning science process skills, increasing their curiosity and adopting science laboratory as unimportant (Yıldız et al., 2006). Kılınç (2018) reported that in-service science teachers had high scores in identifying variables but low scores in decision-making and pre-service science teachers had low scores in general related to experimentation skills. In similar studies, researchers reported that pre-service science teachers' skills at identifying and controlling variables was low (Aydoğdu, 2015; Kozcu Çakır & Sarıkaya, 2018). Other studies' results indicated that pre-service science teachers felt themselves inadequate in designing unassisted experiments due to content knowledge levels and self-confidence perceptions (Dönel Akgül & Geçikli, 2018; Kocakülah & Savaş, 2011; Sujarittham et al., 2019) and had problems in designing controlled experiments as well as reaching conclusion (Dönel Akgül & Geçikli, 2018; Şimşekli, 2018).

In another study about analyzing data, which is one of required factors to design and conduct experiment, it was found that while students having nature of science (NOS) understanding based on "scientific laws are discovered by scientists" tended to think that scientific measurements have high accuracy, students having NOS understanding based on "scientific laws, which are constructed based on observations validated by experiments, are discovery of scientist" tended to think that nature of scientific measurements are not certain (Buffer et al., 2009). The study by Inzunsa and Juarez (2010) indicated that although teachers created appropriate graphs for data, they could not use them for interpretation. Contrary to this, preservice teachers performed well at interpreting data although their conceptual understanding about it were not good (Chabalengula et al., 2012). Related to analyzing validity and reliability of the data, Albers et al. (2008) categorized hierarchically first year university students' understandings about validity of physics experiment based on Bloom taxonomy. According to this categorization, focusing on algorithm/ physical aspects of experiment (rounding numbers up and etc.)/ measurement method correspondences to "remembering level"; focusing on characteristics of variables/ nature of variable to be measured correspondences to "understanding level"; focusing on the quality of measurements correspondences to " applying level"; focusing on the process or the quality of calculations correspondences to "analyzing level" and finally focusing on seeing a pattern correspondences to "synthesizing level" in Bloom taxonomy. At the end of the study, researchers found that first year university students preferred to focus on nature of variables to be measured (understanding level) and on the quality of measurements (applying level).

Purpose of the Study

The main aim of science education all over the world is to teach students to solve problems they faced and IBL is suggested for gaining these skills and competencies to students for many years. Today's learning environments give teachers some roles such as guiding them and being a model for them. Therefore, being adequate in teaching and using IBL in classroom for teachers is important for educating an "inquiring student". Although experimentation is one of the main components of IBL as seen in Figure 1, it was found that studies about experimentation were on the description of both in-service and pre-service teachers' status. Also in these studies, components of experimentation process were not analyzed in detail and studies about factors affecting experimentation process were conducted heavily with students not teachers. Depending on this, it is important to determine science teachers' status about designing experiment and factors affecting this performance to give an effective support to create "inquiring" classes. The aim of this study is to describe science teachers' status about components of experimentation process and determine the effect of given variable type on this performance.

Research problems are presented at the following:
RQ1. How is the status of science teachers' designing experiments performances?
RQ2. How does given variable type affect science teachers' designing experiments performances?

METHODOLOGY

This study was on survey design, which is one of the quantitative descriptive research methods, because it is intended to describe science teachers' status about designing experiments and factors affecting it without any intervention. Besides, the study was also described as cross-sectional survey design because data from participants belonged in the same time (Fraenkel & Wallen, 2003).

Participants

Participants of the study were 72 science teachers who were teaching at middle school level. Convenience sampling technique was used because selecting participants were based on their volunteerism among science teachers who were attending a professional development program coordinated by Provincial Directorate of National Education at that time. 41 of participants (%56,94) was female and 31 of them (%43,06) were male. All participant teachers were working at the center district of the province and %50 of them had 15 years and above professional experience.

Data Collection Tool

Designing Experiments Performance Assessment Form (DEPAF)

DEPAF was developed by the researchers to determine science teachers' status about components of designing experiment. When preparing the form, which has open-ended questions, designing experiment steps proposed by Ergin et al. (2005) were considered. As shown in Figure 2, the form has six questions about determining the purpose of the experiment, identifying variables, explaining steps, collecting and interpreting data, analyzing the results and determining the consistence between the purpose and the results. Content validity of the form was provided by experts of science teaching from the faculty of Education. The experts checked if the DEPAF was addressing the skills of inquiry and specifically designing experiments as well as the problems prepared for the implementation (Figure 2) were suitable or not. After completing the revisions of the experts, the problems and form was also given to two in-service science teachers and five prospective science teachers to confirm its clarity and practicability.

Your problem:

____

What is the reason for choosing this problem? Please explain:

____

____

When designing your experiment, please answer the questions below:

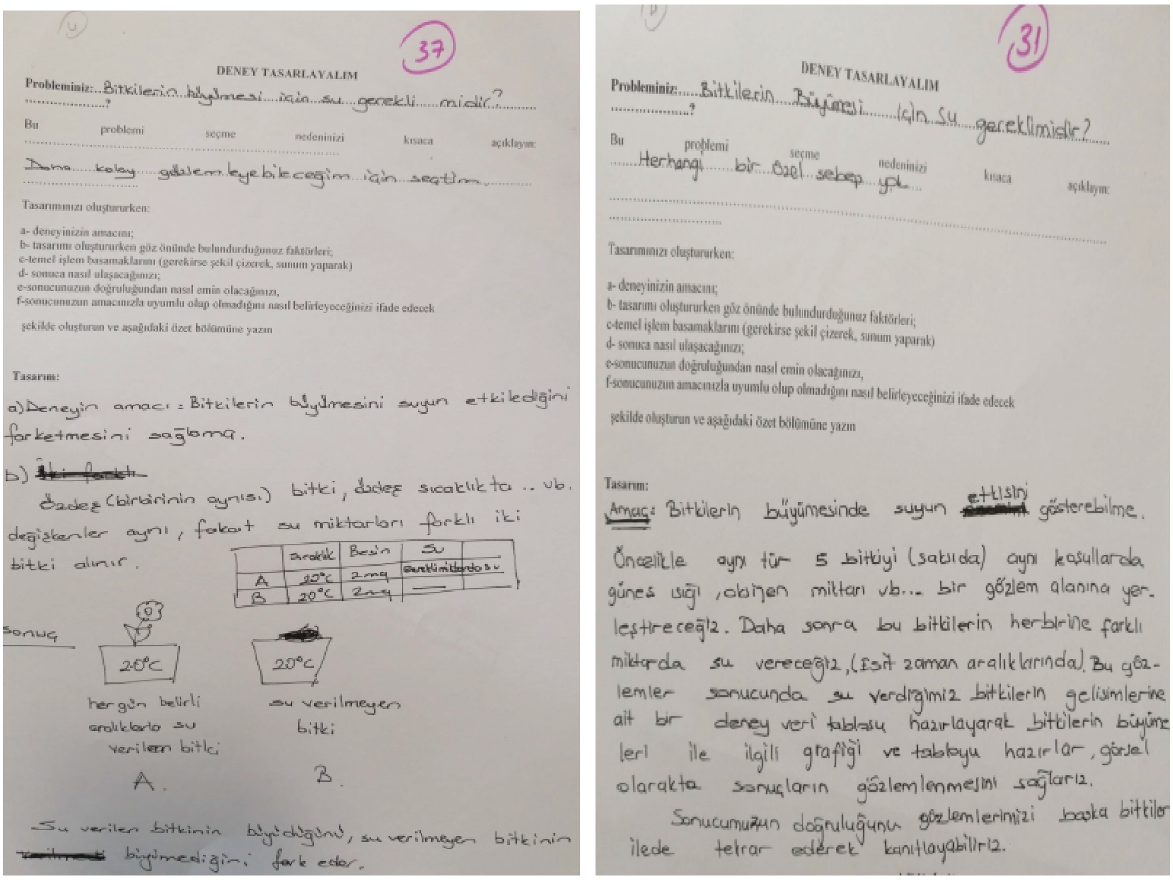
a. What is the purpose of the experiment?
b. Which factor(s) do you consider?
c. What are the steps?
d. How do you get the results?
e. How do you make sure about the accuracy of data?
f. How do you determine if there is a consistence between the purpose and the results or not?

My design:

Figure 2. Designing experiments performance assessment form (DEPAF)

Data Analysis

Obtained data were analyzed via "Designing Experiments Performance Assessment Rubric" (DEPAR) by using descriptive analysis technique. Teachers' answers about components of designing experiments were categorized as "*4=stated and expressed clearly and accurately*", "*3=stated but not expressed clearly and accurately*", "*2= stated partly but not expressed clearly and accurately*" and "*1= not stated, no relevance*" and then scored by one of the researchers. Some completed DEPAF were presented at Figure 3 and scoring process was explained to provide example. Nearly 5 weeks later from the first scoring, same researcher categorized the answers of randomly selected 10 participants and scored them again. 80% agreement within 95% of the codes calculation proposed by Miles and Huberman (1994) was taken into consideration for scoring reliability and finally scoring process was found as reliable.


37

DENEY TASARLAYALIM

Problemimiz: Bitkilerin büyümesi için su gerekli midir?

Bu problemi seçme nedeninizi kısaca açıklayın:

Daha kolay gözlemleyebileceğim için seçtim.

Tasarımınızı oluştururken:

a- deneyinizin amacını;
b- tasarımı oluştururken göz önünde bulundurduğunuz faktörleri;
c-temel işlem basamaklarını (gerekirse şekil çizerek, sunum yaparak)
d- sonuca nasıl ulaşacağınızı;
e-sonucunuzun doğruluğundan nasıl emin olacağınızı,
f-sonucunuzun amacınızla uyumlu olup olmadığını nasıl belirleyeceğinizi ifade edecek

şekilde oluşturun ve aşağıdaki özet bölümüne yazın

Tasarım:

a) Deneyin amacı: Bitkilerin büyümesini suyun etkilediğini farketmesini sağlama.

b) ~~İki farklı~~ özdeş (birbirinin aynısı) bitki, özdeş sıcaklıkta .. vb. değişkenler aynı, fakat su miktarları farklı iki bitki alınır.

	Sıcaklık	Besin	Su
A	20°C	2mg	Belirli miktarda su
B	20°C	2mg	—

Sonuç

20°C 20°C

her gün belirli aralıklarla su verilen bitki A.

su verilmeyen bitki B.

Su verilen bitkinin büyüdüğünü, su verilmeyen bitkinin büyümediğini fark eder.

31

DENEY TASARLAYALIM

Problemimiz: Bitkilerin büyümesi için su gereklimidir?

Bu problemi seçme nedeninizi kısaca açıklayın: Herhangi bir özel sebep yok.

Tasarımınızı oluştururken:

a- deneyinizin amacını;
b- tasarımı oluştururken göz önünde bulundurduğunuz faktörleri;
c-temel işlem basamaklarını (gerekirse şekil çizerek, sunum yaparak)
d- sonuca nasıl ulaşacağınızı;
e-sonucunuzun doğruluğundan nasıl emin olacağınızı,
f-sonucunuzun amacınızla uyumlu olup olmadığını nasıl belirleyeceğinizi ifade edecek

şekilde oluşturun ve aşağıdaki özet bölümüne yazın

Tasarım:

Amaç: Bitkilerin büyümesinde suyun etkisini gösterebilme.

Öncelikle aynı tür 5 bitkiyi (saksıda) aynı koşullarda güneş ışığı, oksijen miktarı vb... bir gözlem alanına yerleştireceğiz. Daha sonra bu bitkilerin herbirine farklı miktarda su vereceğiz, (Eşit zaman aralıklarında) Bu gözlemler sonucunda su verdiğimiz bitkilerin gelişimlerine ait bir deney veri tablosu hazırlayarak bitkilerin büyümeleri ile ilgili grafiği ve tabloyu hazırlar, görsel olarak sonuçların gözlemlenmesini sağlarız.

Sonucumuzun doğruluğunu gözlemlerimizi başka bitkiler ilede tekrar ederek kanıtlayabiliriz.

Figure 3. Some examples from completed DEPAF (In Turkish version)

Both teachers coded as numbers 31 and 37 chose the problem "Do plants need water to grow?" and obtained 4-points for the purpose of experiment by stating it clearly and accurately. While Teacher 31 expressed it as "*To show the effect of water on plant growth*", Teacher 37 as "*The purpose of the experiment: Aware of the effects of water on plant growth*". Teacher 31 answered the question related to factors as "*Identical plants, same environmental factors such as sunlight, O_2 etc. but different amounts of water to each plant at the same time interval*" and she got 4-points. Teacher 37 also got 4-points from determining factors component by expressing it as "*Identical plants, same conditions for each plant except the amount of water*". In explaining the steps component, both teachers got 4-points again while Teacher 31 expressed it through figures as shown in Figure 3 and Teacher 37 expressed it in a written form. Related to getting the results component, Teacher 31 proposed creating a data table which shows the amount of water and plant growth but she could not express it clearly. For example, she could not give information about how she determined the plant growth (increase in the number of leaf or length) and therefore, she got 3-points. Similarly, Teacher 37 created a data table but he could not state how he determined the plant growth and he also got 3-points. In relation to data accuracy, Teacher 31 wrote it as "*we can prove the accuracy of the results by experimenting with other similar plants again*" and got 4-points while Teacher 37 could not give any answer and got 1-point. However, both teachers left the last answer blank and got 1-point.

After scoring, the first research problem was answered by using descriptive statistics and the second one by applying non-parametric tests because the data did not distribute normally (p=.023<.05).

Implementation of the Study

Having two focus questions, this study was firstly aimed to figure out science teachers' designing experiments performances and then to see how it changes depending on variable type that each problem addressed. Therefore, at the beginning, the participants were given time to think about the problems stated in Table 1 and chose one to investigate as well as think about the ways to investigate and solve the problems by using science process skills.

Table 1
Prepared Problems with Different Variable Type

Problems	Given variable type	
	Dependent variable	Independent variable
Does sound spread in space?	No	Yes
Do colors of objects affect the light absorption?	No	Yes
How do temperatures of different substances under the same amount of heat energy change?	Yes	No
Which factors does extension of a spring depend on?	Yes	No
Do plants need water to grow?	No	Yes
How does the strength of electromagnet change when increasing the number of turn?	No	Yes

As seen in Table 1, each problem already has either dependent or independent variable in its sentence structure that was expressed explicitly. Therefore, the structure of the problem may be one of the reasons affecting its preference by the participants. Afterwards, the researchers asked participants why they chose the problem they had and how they can solve it by starting a whole group discussion. As the discussion raised the participants' awareness on both problems and procedure, they are asked to make groups of 3 to 4 according to the problems they chose to investigate. They were told that they are expected to conduct or design an experiment to solve the problems they had. Since some of the problems can easily be conducted at the moment, some need longer periods of time to conduct. Therefore, the researchers went around the groups and just directed questions (ranging from closed ended to open ended) about their plans for reinforcing and encouraging to design and conduct experiments. The groups were given enough time to make preparation and discussions after they were given the DEPAF and told to fill it to note everything they did and to keep their works' progress record. Moreover, they were also told that they are free to take and use the equipment from the material box or shelves that they need for their experiments on their plan. They were given enough time to design, conduct their experiments, collect data, interpret their results and complete the DEPAF.

FINDINGS

In order to answer the first research problem "How is the status of science teachers' designing experiments performances?", firstly mean scores for the components of designing experiment (Figure 4) and then a detailed analysis of scores for each component (Table 2) were presented.

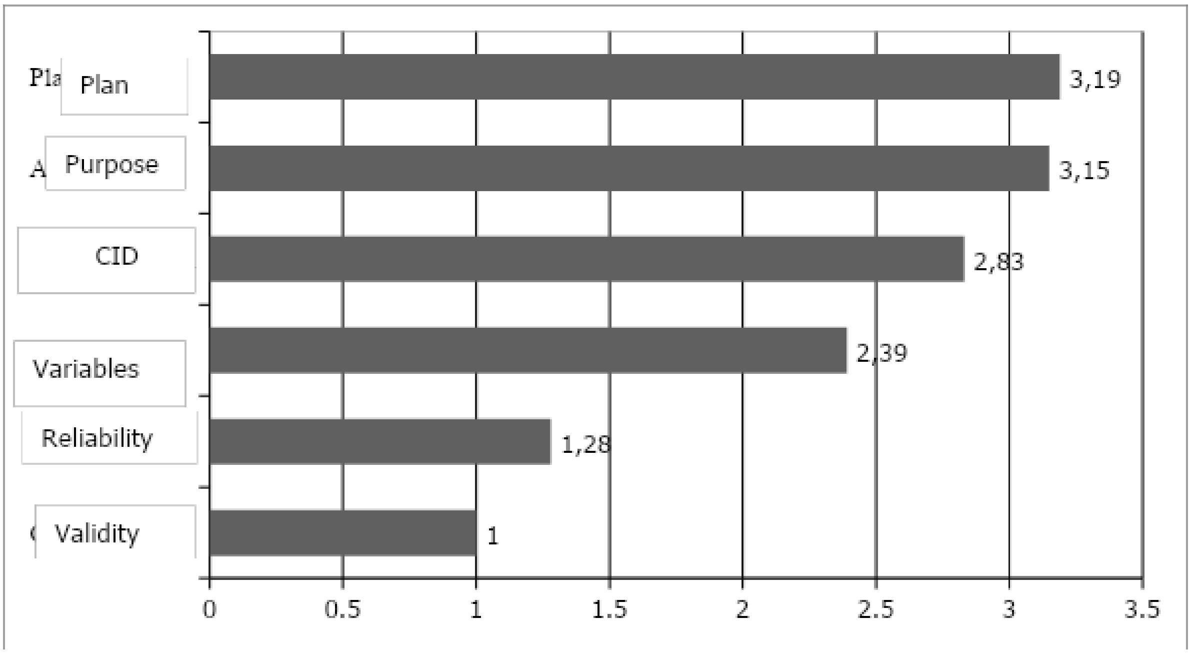


Figure 4. Mean scores of designing experiment components
Note. CID: Collecting and interpreting data

Mean scores showed that although science teachers had better performance in determining the purpose of the experiment and planning the experiment than other components ($X_{purpose}$=3,15/4point; X_{plan}=3,19/4point), they were not good at presenting information about how validity and reliability of experiment data are provided ($X_{validity}$=1/4point; $X_{reliability}$=1,28/4point).

Detailed analysis of teachers' answers about components of designing experiment was presented at Table 2.

Table 2
Descriptive Statistics Values Related to The Components of Designing Experiment

Component	4 point		3 point		2 point		1 point	
	f	%f	f	%f	f	%f	f	%f
Purpose	42	%58,33	14	%19,45	1	%1,39	15	%20,83
Variables	15	%20,83	11	%15,28	33	%45,83	13	%18,06
Plan	41	%56,95	12	%16,67	11	%15,27	8	%11,11
CID	34	%47,22	14	%19,44	2	%2,78	22	%30,56
Reliability	3	%4,17	4	%5,55	3	%4,17	62	%86,11
Validity	-	-	-	-	-	-	72	%100

Note. CID: Collecting and interpreting data

4 point=stated and expressed clearly and accurately; 3=stated but not expressed clearly and accurately; 2= stated partly but not expressed clearly and accurately; 1= not stated, no relevance

Table 2 indicated that more than half of the teachers could state and express the purpose of the experiment completely (58.33%) and 20.83% of them could not state anything or state the purpose with no relevance. In identifying variables component, nearly half of the science teachers (45.83%) could identify variables partly and 18.06% of them could not state anything. However, more than half of the teachers (56.95%) could express the experiment steps completely. In collecting and interpreting data component, nearly half of the science teachers could present complete information, 30.56% of them could not state anything or present information with no relevance. The most problematic components among teachers were about analyzing experiment data. All teachers in validity component and 86.11% of them in reliability component could not express anything.

In order to answer the second research problem "How does given variable type affect science teachers' designing experiments performances?", firstly mean scores of components of designing experiments according to given variable type (Figure 5) and then a detailed analysis of scores for each component according to given variable type (Table 3) were presented. Although the participants worked in groups of 3 to 4 according to the problem they worked on, they actually formed two big groups regarding the type of variable explicitly given in the problem (Table 1).

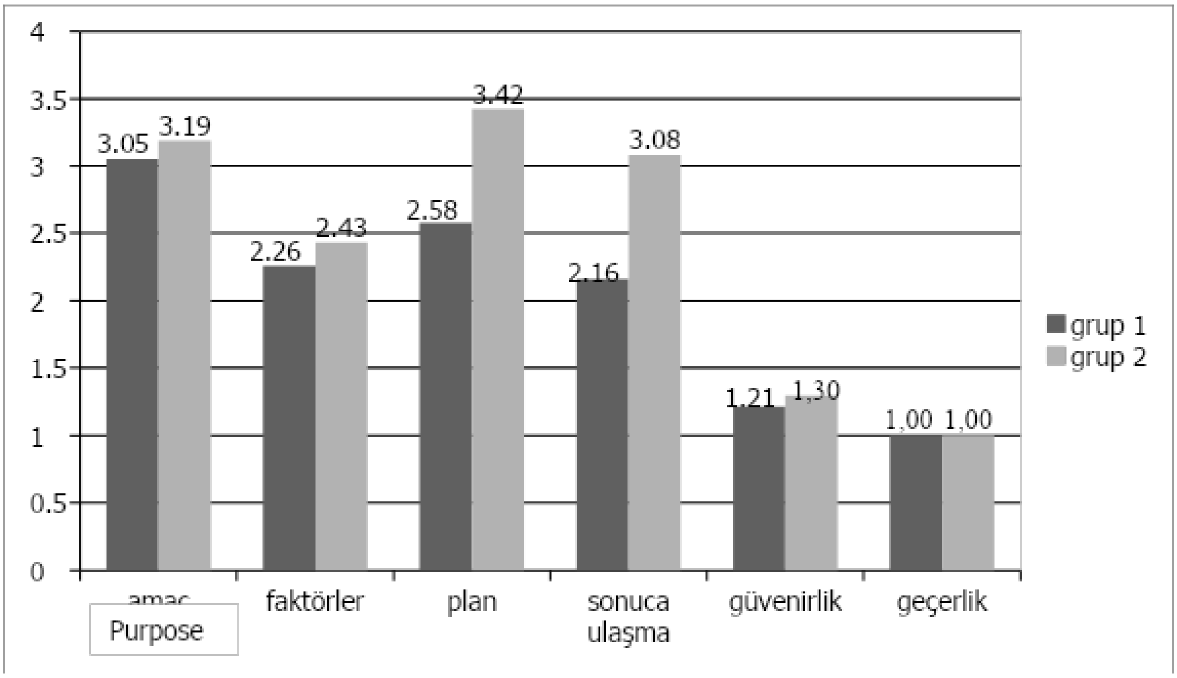


Figure 5. Mean scores for the components of designing experiment according to given variable type

Note. Group 1: Dependent variable available; Group 2: Independent variable available
CID: Collecting and interpreting data

Figure 5 indicated that when independent variable was given, science teachers had higher mean scores in all components of designing experiments (except validity) but especially in planning and collecting and interpreting data. However, there was no difference in mean scores about validity component between two groups.

Table 3
Descriptive Statistics Values Related to Components of Designing Experiment According to Given Variable Type

		4 point		3 point		2 point		1 point	
		f	%f	f	%f	f	%f	f	%f
Purpose	**Group 1**	**11**	**%57.89**	**3**	**%15.79**	**-**	**-**	**5**	**%26.32**
	Group 2	**31**	**%58.49**	**11**	**%20.75**	**1**	**%1.89**	**10**	**%18.87**
Variables	**Group 1**	**2**	**%10.52**	**4**	**%21.06**	**10**	**%52.63**	**3**	**%15.79**
	Group 2	**13**	**%24.53**	**7**	**%13.20**	**23**	**%43.40**	**10**	**%18.87**

Plan	Group 1	7	%36.84	3	%15.79	3	%15.79	6	%31.58
	Group 2	34	%64.15	9	%16.98	8	%15.10	2	%3.77
CID	Group 1	4	%21.05	5	%26.32	-	-	10	%52.63
	Group 2	30	%56.60	9	%16.98	2	%3.77	12	%22.65
Reliability	Group 1	1	%5.26	-	-	1	%5.26	17	%89.48
	Group 2	2	%3.77	4	%7.55	2	%3.77	45	%84.91
Validity	Group 1	-	-	-	-	-	-	19	%100
	Group 2	-	-	-	-	-	-	53	%100

Note. CID: Collecting and interpreting data

4 point=stated and expressed clearly and accurately; 3=stated but not expressed clearly and accurately; 2= stated partly but not expressed clearly and accurately; 1= not stated, no relevance

Group 1: dependent variable available; Group 2: independent variable available

Table 3 showed that both groups performed nearly the same in stating the purpose of the experiment completely (Group $1_{purpose}$=57.89%, Group $2_{purpose}$=58.49%). In identifying variables component, the highest percentages for both groups belonged to "2 point" categorization (Group $1_{variables}$= 52.63%, Group $2_{variables}$= 43.40%). In reliability component, both groups could not state anything or present information with no relevance (Group $1_{reliability}$= 89.48%, Group $2_{reliability}$= 84.91%). However, more science teachers could get "4 points" in planning and CID components when independent variable given (Group 1_{plan}= 36.84%, Group 2_{plan}= 64.15%; Group 1_{CID}= 21.05%, Group 2_{CID}=56.60%). Further, giving different variables had no difference in determining the validity of experiment; both groups could not state anything about this component.

Although findings pointed out that science teachers who designed experiments with only independent variable performed better, this was also examined in terms of statistical significance. Therefore, teachers' both total and each component scores were calculated and tested for normal distribution. Normality test results showed that the scores did not distribute normally (Z_{total}=.106, p_{total}=.045; $Z_{purpose}$=.344, $p_{purpose}$=.000; $Z_{variables}$=.288, $p_{variables}$=.000; Z_{plan}=.344, p_{plan}=.000; Z_{CID}=.285, p_{CID}=.000; $Z_{reliability}$=.505, $p_{reliability}$=.000) so, analysis was conducted by Mann-Whitney U test and obtained results were presented at Table 4.

Table 4

U Test Results for Total and Each Component Scores of Designing Experiment According to Given Variable Type

Component	Group	*n*	*Mean rank*	*Sum of ranks*	*Z*	*p*	*r*
Purpose	1	19	35,63	677,00	-.238	.812	-
	2	53	36,81	1951,00			
Variables	1	19	34,68	659,00	-.468	.639	-
	2	53	37,15	1969,00			
Plan	1	19	26,82	509,50	-2.619	.009*	.308
	2	53	39,97	2118,50			
CID	1	19	26,03	494,50	-2.743	.006*	.323
	2	53	40,25	2133,50			
Reliability	1	19	35,29	670,50	-.489	.625	-

	2	53	36,93	1957,50			
Validity	1	19	36,50	693,50	.000	1.00	-
	2	53	36,50	1934,50			
Toplam Puan	1	19	26,42	502,00	-2.459	.014*	.289
	2	53	40,11	2126,00			

Note. *p<.05

CID: Collecting and interpreting data
Group 1: dependent variable available; Group 2: independent variable available

Table 4 showed that science teachers who designed experiments with only independent variable had higher mean scores for both total and each component (except validity) of designing experiment. Findings showed that given variable type had significant but small effect on total scores of designing experiment ($Z_{total}(71)=-2.459$, $p=.014<.05$, $r=.289$) and significant but medium effect on planning and CID performances ($Z_{plan}(71)= -2.619$, $p=.009<.05$, $r=.308$; $Z_{CID}(71)= -2.743$, $p=.006<.05$, $r=.323$).

DISCUSSION

As intended in this study, which was based on quantitative survey design with participation of 72 science teachers who were selected via convenience sampling technique, to describe science teachers' performances about designing experiment and determine how given variable type affects these performances. Analyses for answering the first research question "How is the status of science teachers' designing experiments performances?" showed that science teachers were better at determining the purpose of the experiment and planning components. Besides, only 20.83% of teachers could identify variables completely and accurately, 86.11% of them could not state anything about reliability of experiment. The question about presenting information for providing validity of experiment was left blank by all the teachers.

The reason for the problems teachers had in identifying variables and determining the reliability and validity although they could express the steps and determine the purpose of experiment may depend on inquiry level used in classroom. Designing experiment is one of the components of IBL as shown in Figure 1. Therefore, the deficiencies in the components of designing experiments may stem from the use of inquiry in the classes. As Bell et al. (2005) said, a teacher may use structure-inquiry which problem, method and results are all presented to students. He/she may give only results/ method and results or may not present any information except problem statement as in our case. This preference is related to teacher's effort to make his/her lesson more student-centered. However, there are studies reported that teachers have some difficulties about implementing inquiry with high level (Bodzin & Beerer, 2003; Kim et al., 2013; Kinyota, 2020; On, 2010; Shedletzky & Zion, 2005). Similarly, Kaya et al. (2021) expressed that teachers have high efficacy in implementing teacher-centered inquiry. Depending on these results, findings in Figure 4 and Table 2 can be explained as participant teachers may implement structured inquiry in their lessons and they may prefer close-ended, structured, prescription type experiments (Tobin et al., 1994). In such situation, teachers may not dwell on identifying variables or analyzing validity and reliability. In furtherance, studies reported that most of time in experimentation process was allocated to collecting data and conducting experiment rather than discussing data or generating new ideas (Kuhn, 1993) and discussion sessions after experimentation were heavily on scientific phenomena or method used rather than experiment results (Jimenez Aleixandre et al., 2000).

Analyses for answering the second research question "How does given variable type affect science teachers' designing experiment performance?" showed that mean scores of teachers who designed experiment with problem having only independent variable were higher in especially planning and collecting and interpreting data components and both total scores and scores of these two components (planning, collecting and interpreting data) were statistically significant. Further data indicated that teachers in both groups performed nearly same in determining purpose, identifying variables and analyzing validity and reliability. However, apart from given variable type, teachers in both groups could not express anything about validity of the experiment.

It is thought that the primary reason for the finding that indicating teachers who designed experiment with problem having only dependent variable had significantly lower performance than other teachers who designed experiment with problem having only independent variable may be related to science teachers' content knowledge. In experimentation process, while dependent variable is related to properties measured, independent variable is related to factors affecting the measurement (Barton, 1997). In order to exemplify this, we can look closer to the problem '*Do plants need water to grow?'* In this problem, the test factor or in other words the independent variable is the existence of water. In experimentation process, teacher will give water to one of identical plants and then measure its length in height or increase in numbers of leaves and she/he will not give any water to other plant. But, if this problem was as "Which factors do plants need to grow?", then teachers would determine the affecting factors for plant growth such as water or light existence, type of soil, color of light and etc. depending on his/her content knowledge. For this reason, only teachers having solid content knowledge can determine the factors related to the problem. Supporting this, van Riesen et al. (2018) stated that having prior knowledge about the content of experiment is important to design and conduct it. Similarly, Zhou et al. (2016) reported that experiment content has an effect on identifying variables. Secondarily, the problem that teachers have when they designed experiment with only dependent variable may stem from their misconceptions or assumptions. Boudreaux et al. (2008) reported that individuals sometimes make mistakes when they identify variables that affect or determine the dependent variable and they tend to focus only one factor among all factors, which can affect the measurement. Corroborating our results, Lazonder and Kamp (2012) pointed out those students, who could generate their own research problems in inquiry process, tended to focus only one factor among all possible factors that can affect the dependent variable.

The lack of validity and reliability of data in teachers' experiments led us to think that participant teachers' nature of science understanding were not enough. Buffer et al. (2009) found that while students which had nature of science (NOS) understanding based on "scientific laws are discovered by scientists" tended to think that scientific measurements have high accuracy, students having NOS understanding based on "scientific laws, which are constructed based on observations validated by experiments, are discovery of scientist" tended to think that nature of scientific measurements are not certain and they specified that nature of science understanding shapes the understanding about nature and accuracy of scientific measurement. Besides, Roberts and Johnson (2015) proposed that validity of data depends on the variables of the experiment and measurements. From this perspective, the problem that teachers have in identifying variables may be the reason of the problems that they have in determining the validity and reliability.

CONCLUSIONS AND SUGGESTIONS

Based on the findings, we can conclude that science teachers have problems in identifying variables and determining the validity and reliability although they are good at determining the purpose of the experiment and collecting and interpreting data. We think that these problems are related to teachers' preferences about inquiry level (structured, guided, or open inquiry) and experiment type (close or open ended) in the classroom. We believe that if teachers prefer guided or open inquiry in their classroom by considering their students' grade level and engage their students into experimentation process mentally by preparing worksheets, then teachers' experimentation skills such as determining validity and reliability or identifying variables may improve. In addition, we suggest to teachers to engage students into discussion sessions focused on comparing and evaluating experimental results after experimentation. Besides, new research may be conducted to examine teachers' difficulties in determining validity and reliability and identifying variables in detail and to develop and improve teachers' nature of science understanding.

We also conclude that science teachers who designed experiments with problems having only independent variable had better performances than other teachers did. We think the stem of this problem may be teachers' content knowledge level and their misconceptions or assumptions. We propose to teach experimentation directly and explicitly to overcome this problem. In this way, teachers may use their content knowledge effectively in experimentation after learning what variable is, how the data can be collected and interpreted.

REFERENCES

Albers, C., Rollnick, M., & Lubben, F. (2008). First year university students' understanding of validity in designing a physics experiment. *African Journal of Research in Mathematics, Science and Technology Education, 12*(1), 33-54. https://doi.org/10.1080/10288457.2008.10740627

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry? *Journal of Science Teacher Education, 13*(1), 1-12. https://doi.org/10.1023/A:1015171124982

Aydoğdu, B. (2015). Examining preservice science teachers' skills of formulating hypotheses and identifying variables. *Asia-Pacific Forum on Science Learning and Teaching, 16*(1), 1-36.

Barton, R. R. (1997). Pre-experiment planning for designed experiments: Graphical methods. *Journal of Quality Technology, 29*(3), 307-316. https://doi.org/10.1080/00224065.1997.11979772

Belet Boyacı, Ş. D. & Güner Özer, M. (2019). Öğrenmenin geleceği: 21. yüzyıl becerileri perspektifiyle Türkçe dersi öğretim programları [The future of learning: Turkish language course curricula from the perspective of 21st century skills]. *Anadolu Journal of Educational Sciences International, 9*(2), 708-738. https://doi.org/10.18039/ajesi.578170

Bell, R. L., Smetana, L., & Binns, I. (2005). Simplifiying inquiry instruction. *The Science Teacher, 72*(7), 30-33. Simplifying_inquiry_instruction20170105-19904-1wplamd.pdf (d1wqtxts1xzle7.cloudfront.net)

Boudreaux, A., Shaffer, P. S., Heron, P. R.L., & McDermott, L. C. (2008). Student understanding of control of variables: Deciding whether or not a variable influences the behavioor of a system. *American Journal of Physics, 76*(2), 163-170. https://doi.org/10.1119/1.2805235

Buffler, A., Lubben, F., & Ibrahim, B. (2009). The relationship between students' views of the nature of science and their views of the nature of scientific measurement. *International Journal of Science Education, 31*(9), 1137-1156. https://doi.org/10.1080/09500690802189807

Chabalengula, V.M., Mumba, F. & Mbewe, S. (2012). How pre-service teachers' understand and perform science process skills. *Eurasia Journal of Mathematics, Science & Technology Education, 8*(3), 167-176. http://dx.doi.org/10.12973/eurasia.2012.832a

Chu, S.K.W., Tavares, N. J., Chu, D., Ho, S. Y., Chow, K., Siu, F.L. C. & Wong, M. (2012). *Developing upper primary students' 21st century skills: Inquiry learning through collaborative teaching and Web 2.0. technology*. Hong Kong Centre for Information Technology in Education. http://web.hku.hk/~samchu/docs/Chu-2012-Developing-upper-primary-students-21st-century-skills.pdf

Cohen, J. D., Renken, M. & Calandra, B. (2017). Urban middle school students, twenty-first century skills and STEM-ICT careers: Selected findings from a front-end analysis. *TechTrends, 61*, 380-385. https://doi.org/10.1007/s11528-017-0170-8.

Dönel Akgül, G. & Geçikli, E. (2018). Öğretmen adaylarının yeni bir deney tasarlayabilme ve uygulayabilme hakkındaki görüşleri [Opinions of science teacher candidates about being able to design and conduct a new experiment]*. Bayburt Eğitim Fakültesi Dergisi, 13*(26), 349-364. https://dergipark.org.tr/tr/download/article-file/614489

Ergin, Ö., Pekmez Şahin, E. & Öngel Erdal, S. (2005). *Kuramdan uygulamaya deney yoluyla fen öğretimi [Science teaching through experimentation from theory to practice] (1st Edition).* Dinazor Kitabevi.

Fandino Parra, Y. (2013). 21st century skills and the English foreign language classroom: A call for more awareness in Colombia. *Gist: Education and Learning Research Journal, 7*, 190-208. https://latinjournal.org/index.php/gist/article/view/622

Farisi, M. I. (2016). Developing the 21st-century social studies skills through technology integration. *Turkish Online Journal of Distance Education, 17*(1), 16-30. https://files.eric.ed.gov/fulltext/EJ1092803.pdf

Fraenkel, J. R. & Wallen, N.E. (2003). *How to design and evaluate research in education (5th Edition).* McGraw- Hill Companies.

Inzunsa, S. & Juarez, J. A. (2010). High school teachers' reasoning about data analysis in a dynamic statistical environment. In C. Reading (Ed.), *Data and context in statistics education: Towards an evidence-based society. Proceedings of the Eighth International Conference on Teaching Statistics (ICOTS8)*. International Statistical Institute.

Jimenez-Aleixandre, M. P., Bugallo Rodriguez, A. & Duschl, R. A. (2000). "Doing the lesson" or "Doing science": Argument in high school genetics. *Science Education, 84*(6), 757–792. https://doi.org/10.1002/1098-237X(200011)84:6<757::AID-SCE5>3.0.CO;2-F

Kaya, F., Borgerding, L. A., & Ferdous, T. (2021). Secondary science teachers' self-efficacy beliefs and implementation of inquiry. *Journal of Science Teacher Education, 32*(1), 107-121. https://doi.org/10.1080/1046560X.2020.1807095

Kılınç, H. S. (2018). *Fen bilgisi öğretmenlerinin ve öğretmen adaylarının bilimsel süreç becerilerine sahip olma düzeylerinin incelenmesi: Ölçek geliştirme ve uygulama çalışması [Examination of the level of having science process skills of science teachers and science prospective teachers: Measurement tool development and application study] (Publication No:517649)* [Master's thesis, Mersin University]. The Council of Higher Education National Dissertations and Theses Centre.

Kim, M., Tan, A. L., & Toralballa Talaue, F. (2013). New vision and challenges in inquiry-based curriculum change in Singapore. *International Journal of Science Education, 35*(2), 289-311. https://doi.org/10.1080/09500693.2011.636844

Kinyota, M. (2020). The status of and challenges facing secondary science teaching in Tanzania: A focus on inquiry-based science teaching and the nature of science. *International Journal of Science Education, 42*(13), 2126-2144. https://doi.org/10.1080/09500693.2020.1813348

Kocakülah, A. & Savaş, E. (2011). Fen bilgisi öğretmen adaylarının deney tasarlama ve uygulama sürecine ilişkin görüşleri. *Ondokuz Mayıs Üniversitesi Eğitim Fakültesi Dergisi, 30*(1), 1-28. https://dergipark.org.tr/tr/download/article-file/188019

Kozcu Çakır, N. & Sarıkaya, M. (2018). Fen bilgisi öğretmen adaylarının bilimsel süreç becerilerinin değerlendirilmesi. *Turkish Studies,13*(4), 859-884. http://dx.doi.org/10.7827/TurkishStudies.12823

Kuhlthau, C., Maniotes, L. & Caspari, A. (2015). Guided Inquiry: Learning in the 21st Century, 2nd Edition. Retrieved from http://publisher.abc-clio.com/9781440833823

Kuhn, D. (1993). Science as argument: Implications for teaching and learning scientific thinking. *Science Education, 77*, 319–337. https://doi.org/10.1002/sce.3730770306

Larson, L. C. & Northern Miller, T. (2011). 21st century skills: Prepare students for the future. *Kappa Delta Pi Record, 47*(3), 121-123. https://doi.org/10.1080/00228958.2011.10516575

Lazonder, A. W., & Kamp, E. (2012). Bit by bit or all at once? Splitting up the inquiry task to promote children's scientific reasoning. *Learning and Instruction, 22*(2012), 458-464. https://doi.org/10.1016/j.learninstruc.2012.05.005

Lee, C. A., & Houseal, A. (2003). Self-efficacy, standards and benchmarks as factors in teaching elementary school science. *Journal of Elementary Science Education, 15*(1), 37-56. https://doi.org/10.1007/BF03174743

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.

National Research Council (1996). *National Science Education Standarts*. National Academy Press.

On, C. H. (2010). How do teachers' beliefs affect the implementation of inquiry-based learning in the PGS curriculum? A case study of two primary schools in Hong Kong [Doctoral Dissertation, Durham University]. Durham e-Theses Archive. http://etheses.dur.ac.uk/320/

Partnership for 21st Century Skills (2009). *A. framework for 21st century learning*. Tucson: AZ: P21. www.21stcenturyskills.org.

Pedaste, M., Maeots, M., Siiman, L. A., Jong, T., van Riesen, S. A. N., Kamp, E. T., Manoli, C. C., Zacharia, Z. C. & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review, 14*, 47-61. http://dx.doi.org/10.1016/j.edurev.2015.02.003

Pyatt, K. & Sims, R. (2012). Virtual and physical experimentation in inquiry-based science labs: Attitudes, performance and Access. *Journal of Science Education and Technology, 21*, 133-147. https://doi.org/10.1007/s10956-011-9291-6

Rahayu, S. (2017). Promoting the 21st century scientific literacy skills through innovative chemistry instruction. *AIP Conference Proceedings, 1911*, 1-8. https://doi.org/10.1063/1.501601

Roberts, R., & Johnson, P. (2015). Understanding the quality of data: a concept map for "the thinking behind the doing" in scientific practice. *The Curriculum Journal, 26*(3), 345–369. https://doi.org/10.1080/09585176.2015.1044459

Shedletzky, E., & Zion, M. (2005). The essence of open-inquiry teaching. *Science Education International, 16*(1), 23-38. http://www.icaseonline.net/sei/16-01-2005/16-01-2005-23_38.pdf

Sujarittham, T., Tanamatayarat, J. & Kittiravechote, A. (2019). Investigating the students' experimental design ability toward guided inquiry based learning in the physics laboratory course. *TOJET: The Turkish Online Journal of Educational Technology, 18*(1), 63-69. https://files.eric.ed.gov/fulltext/EJ1201681.pdf

Şimşekli, Y. (2018). Investigation of the experiment design skills of biology and science teachers and preservice teachers. *Journal of Education and Training Studies, 6*(9), 199-207. https://files.eric.ed.gov/fulltext/EJ1189760.pdf

Tobin, K., Tippins, D. J., & Gallard, A. J. (1994). Research on instructional strategies for teaching science. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning (pp. 45–93)*. Macmillan.

Trnova, E. & Trna, J. (2006, November 8-11). *Science experimental skills under development* [Paper Presentation] 5th IOSTE Eastern and Central European Symposium, University of Tartu, Estonia.

Uluçınar Sağır, Ş., & Aslan, O. (2009). Fen bilgisi öğretmen adaylarının özyeterlik inançlarının çeşitli değişkenler açısından incelenmesi. *E-Journal of New World Sciences Academy, 4*(2), 462-475. https://dergipark.org.tr/tr/download/article-file/185947

van Riesen, S. A. N., Gijlers, H., Anjewierden, A. & Jong, T. (2018). The influence of prior knowledge on experiment design guidance in a science inquiry context, *International Journal of Science Education, 40*(11), 1327-1344. https://doi.org/10.1080/09500693.2018.1477263

Yıldız, E., Akpınar, E., Aydoğdu, B. & Ergin, Ö. (2006). Fen bilgisi öğretmenlerinin fen deneylerinin amaçlarına yönelik tutumları. *Türk Fen Eğitimi Dergisi, 3*(2), 2-18. https://dergipark.org.tr/tr/download/article-file/43756

Zhou, S., Han, J., Koenig, K., Raplinger, A., Pi, Y., Li, D., Xiao, H., Fu, Z., & Bao, L. (2016). Assessment of scientific reasoning: The effects of task context, data and design on student reasoning in control of variables. *Thinking Skills and Creativity, 19*, 175-187. https://doi.org/10.1016/j.tsc.2015.11.004